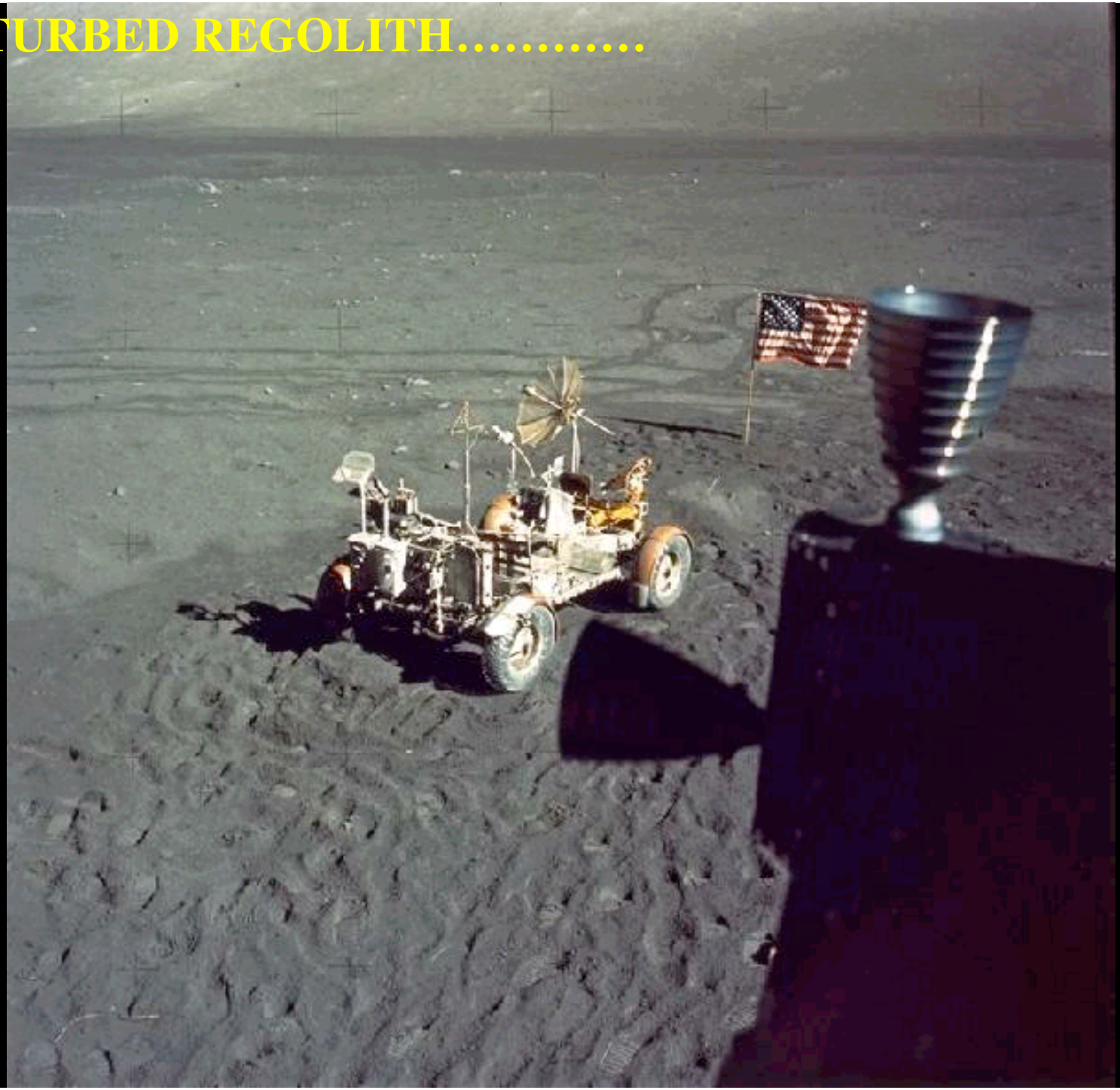

THE APOLLO EXPERIENCE
BREAKING NEWS!
MOUNTAIN LION AT AMES!!!
HARRISON H. SCHMITT
UNIVERSITY OF WISCONSIN-MADISON

THE REGOLITH……..

DISTURBED REGOLITH……



The only Weathering and Erosional Agents on the Moon are Meteorite and Micrometeorite Impact and the Solar Wind.

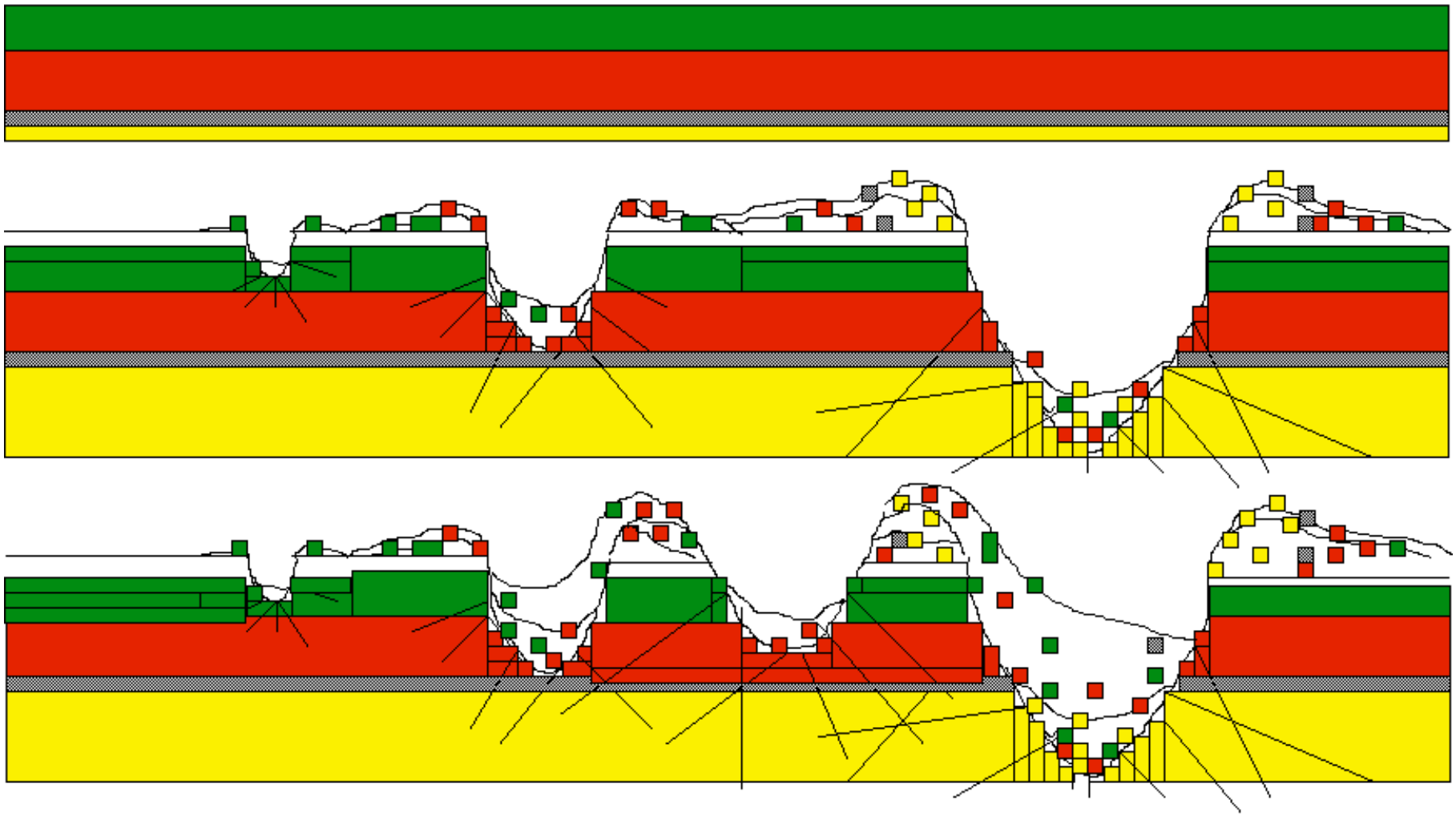
BASIC PROCESSES IN LUNAR SOIL FORMATION

- ***COMMINUTION:*** **breaking of rocks, minerals, and glasses into smaller particles;**
- ***AGGLUTINATION:*** **welding of rock, mineral, and glass fragments together by micrometeorite-produced, impact-generated melt (quenched to glass);**
- ***IMPACT-MELT VAPORIZATION AND DEPOSITION:*** **Vaporization of components in the micrometeorite-produced, impact- generated melt with loss and re-deposition of volatiles.**
- ***SOLAR-WIND SPALLATION AND PARTICLE IMPLANTATION:*** **Erosion and vaporization caused by sputtering from impacting high-energy particles;**

Space Weathering

Cumulative Effects due to :

- **Deep Vacuum : ~10^{-12} torr**
- **Micrometeorite Impact : Velocities to >>10^{5} km/hr**
- **Radiation: Solar-wind Particles / Galactic / Cosmic**
- **Temperature : +125 °C to -240 °C**



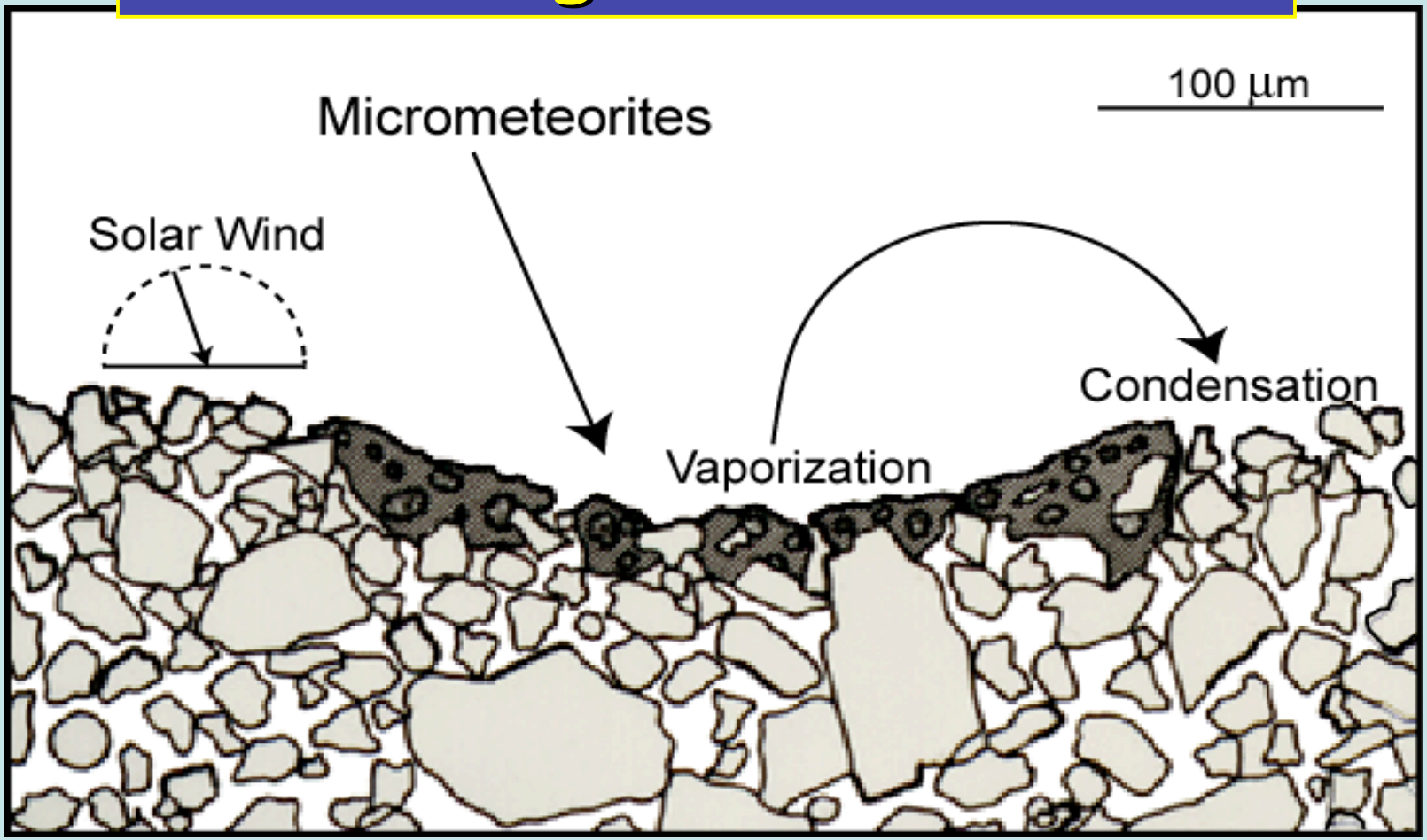
CONCEPTUAL DEVELOPMENT OF LUNAR REGOLITH IN MARE BASINS

APPROXIMATE SCALE 1CM = 10 M

BASALT UNITS

REGOLITH UNITS

Lunar Regolith Formation



Comminution, Agglutination, & Vapor Deposition

The Major Weathering and Erosional agent on the Moon is Meteorite and Micrometeorite Impact

REGOLITH SUMMARY - 1

- **REGOLITH (mantle of fragmental, unconsolidated material overlying bedrock)**
  - **>6M DEEP ON 3.8 B.Y. OLD SURFACES**
- **CONSTITUENTS:**
  - **ROCK FRAGMENTS**
  - **MINERAL FRAGMENTS**
  - **VOLCANIC GLASS SPHERES AND FRAGMENTS**
  - **AGGLUTINATES (IMPACT GLASS WELDING TOGETHER ROCK, MINERAL & GLASS FRAGMENTS)**
  - **METEORITIC CONTAMINATION (<0.3%)**
  - **ADSORBED SOLAR WIND VOLATILES**
  - **PRODUCTS OF SOLAR AND COSMIC RADIATION**

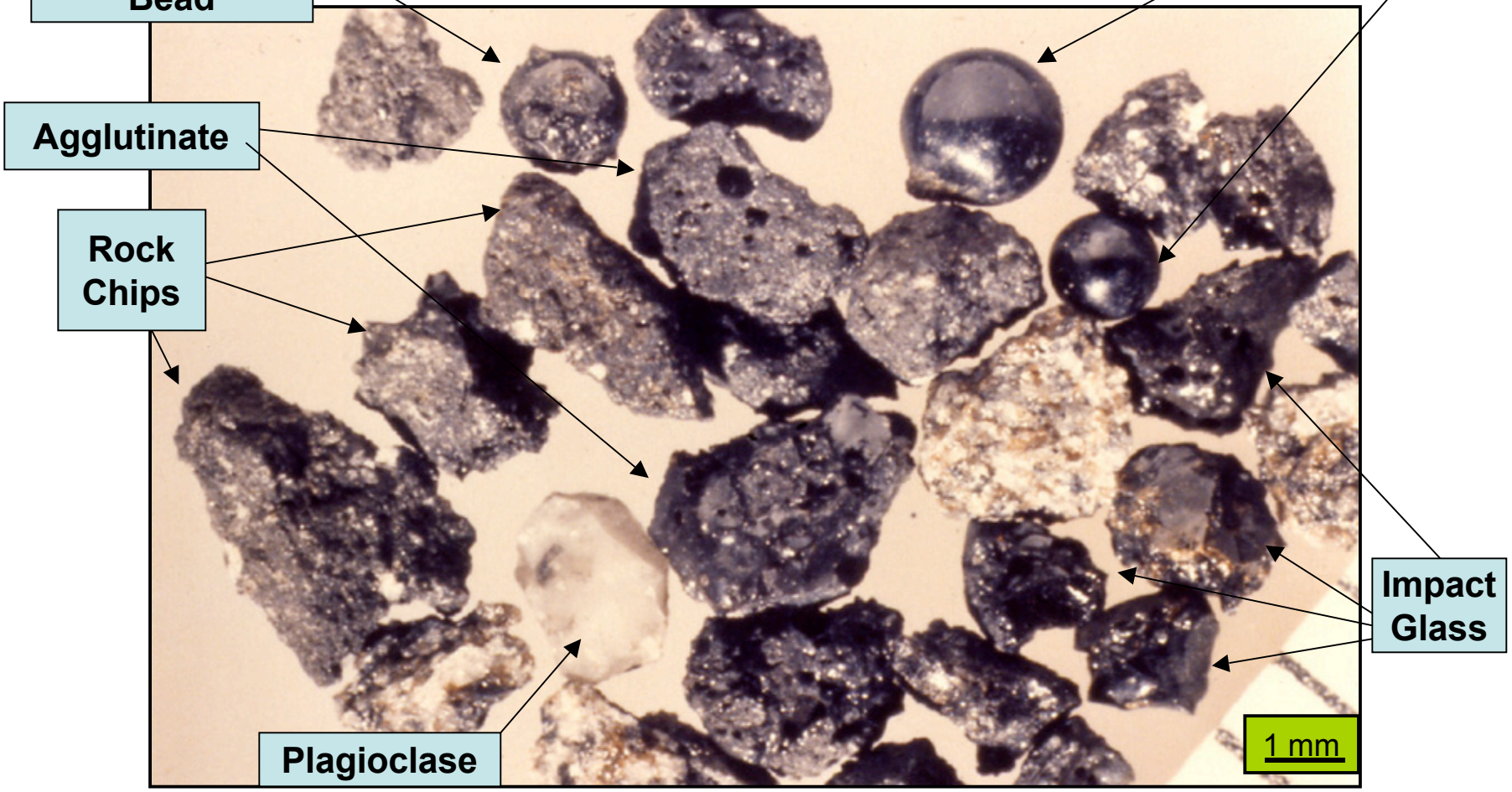
REGOLITH SUMMARY - 2

- **LATERAL MIXING RATE**
  - **ON THE ORDER OF 10S OF METERS PER 100 MY**
  - **~100S OF METERS PER BILLION YEARS SINCE 3.8 B.Y. AGO**
- **VERTICAL MIXING IRREGULAR**
  - **3M DRILL CORES INDICATE TEXTURAL LAYERING BUT NO SIGNIFICANT AVERAGE CHEMICAL CHANGE WITH DEPTH**

REGOLITH SUMMARY - 3

- **GEOTECHNICAL PARAMETERS (ENGINEERING DESIGN CONSTRAINTS)**
  - **DENSITY ~1.9 GM/CM^3**
  - **HIGH BEARING STRENGTH**
  - **LOW COHESION (~DAMP BEACH SAND)**
  - **>60% PARTICLES <100m (THAT IS, PENETRATING DUST!!!!!)**
  - **HIGHLY ABRASIVE (THAT IS, RELIABLE SEALS REQUIRED!!!!)**
  - **DISSEMINATED, FINE GRAIN NATIVE IRON**
  - **DISSEMINATED, FINE GRAIN IRON SULFIDE**
  - **HIGHLY REDUCING (HYDROGEN)**

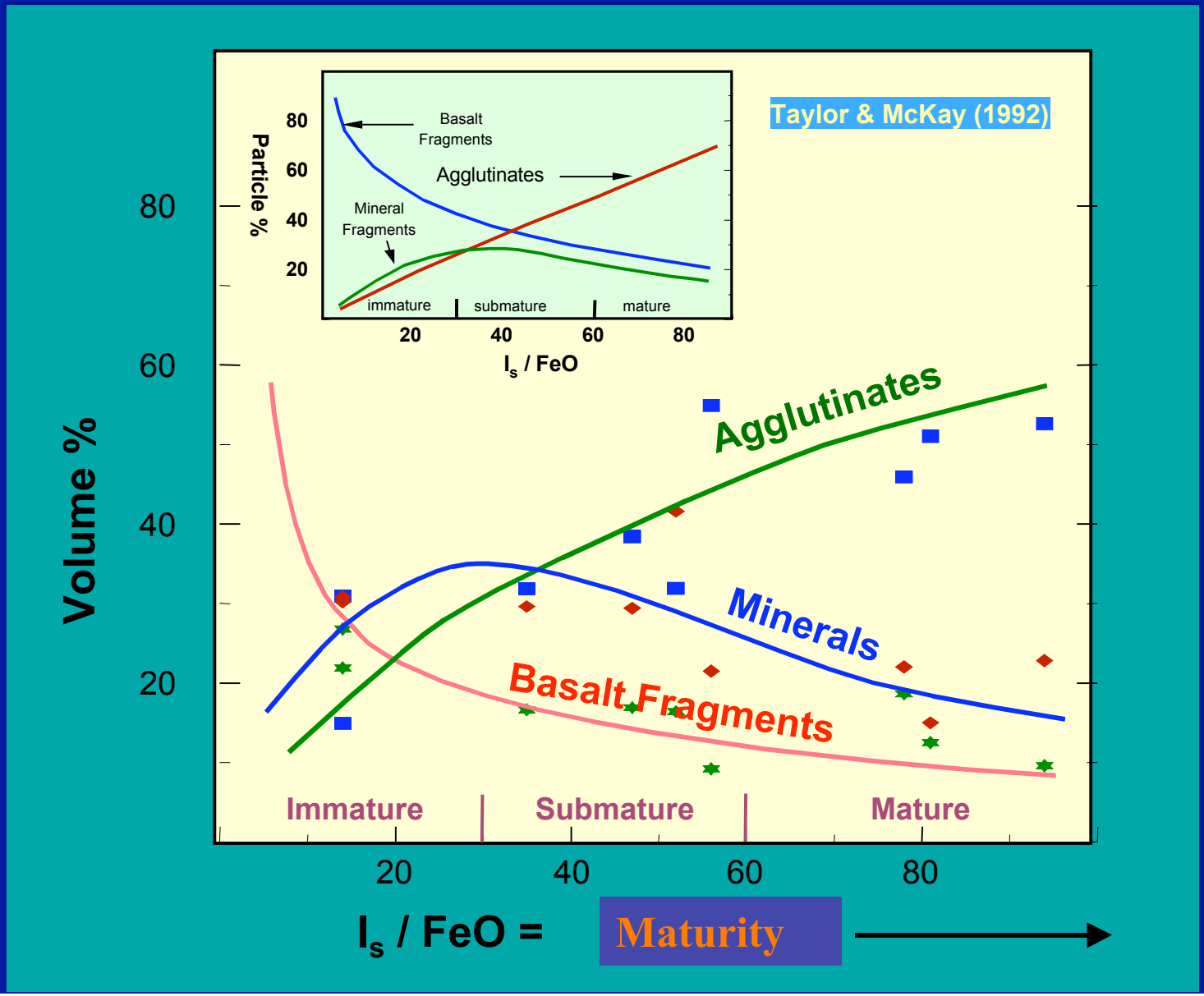
Lunar Mare Soil



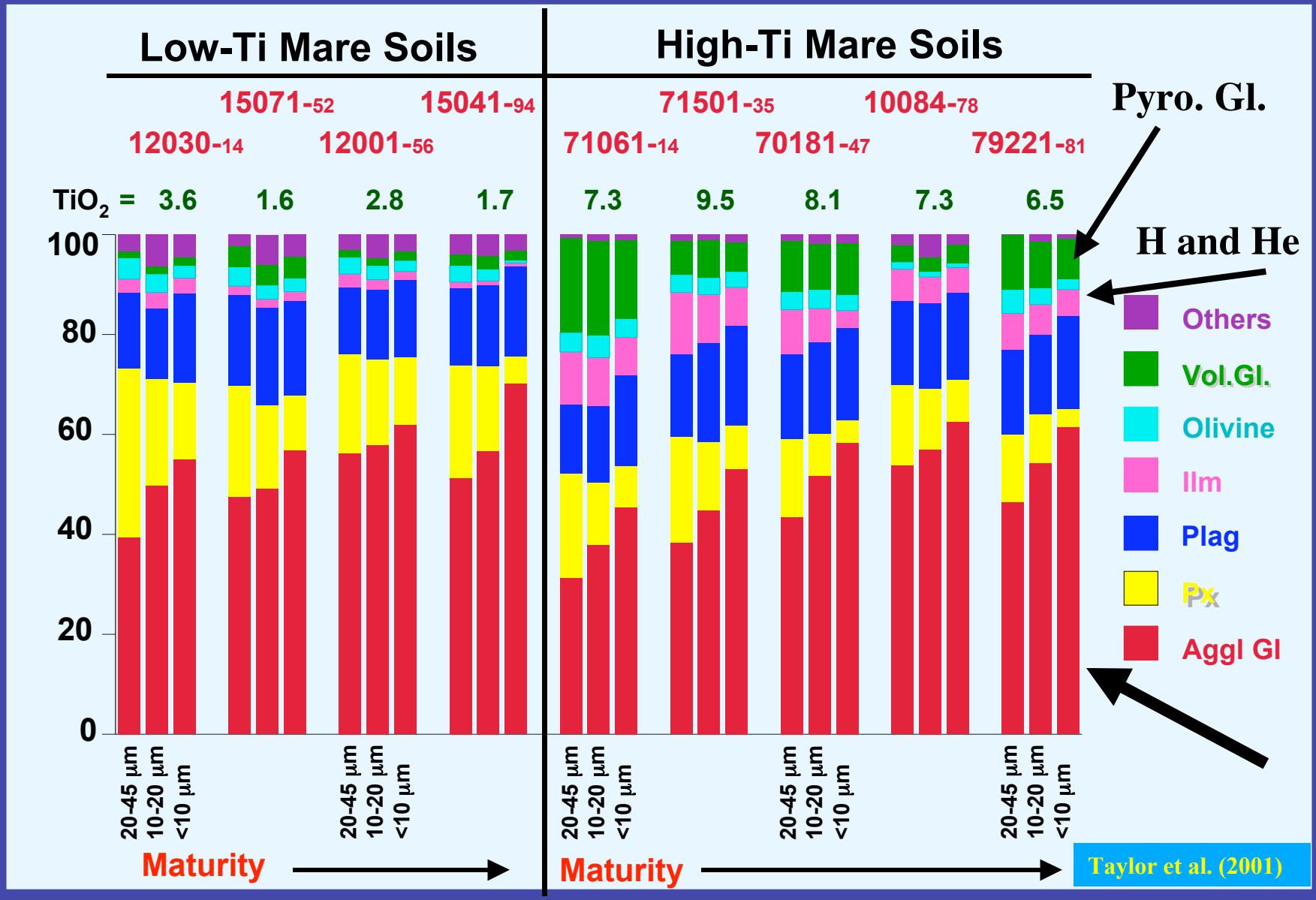
Regolith: broken up rock material; Fines: <1 cm portion of the Regolith

Dust: < 50 μm portion of the Soil

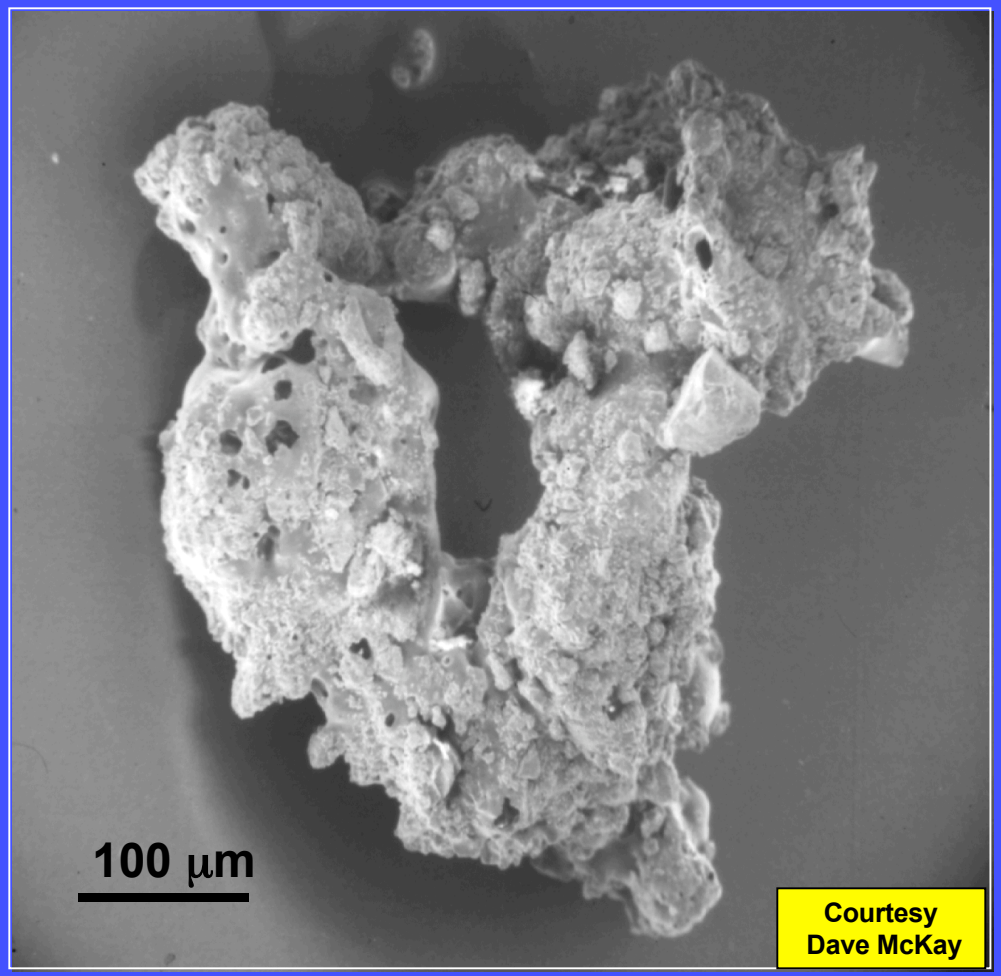
Mare Soil Maturation



Cumulative Modal Abundances of Mare Soils

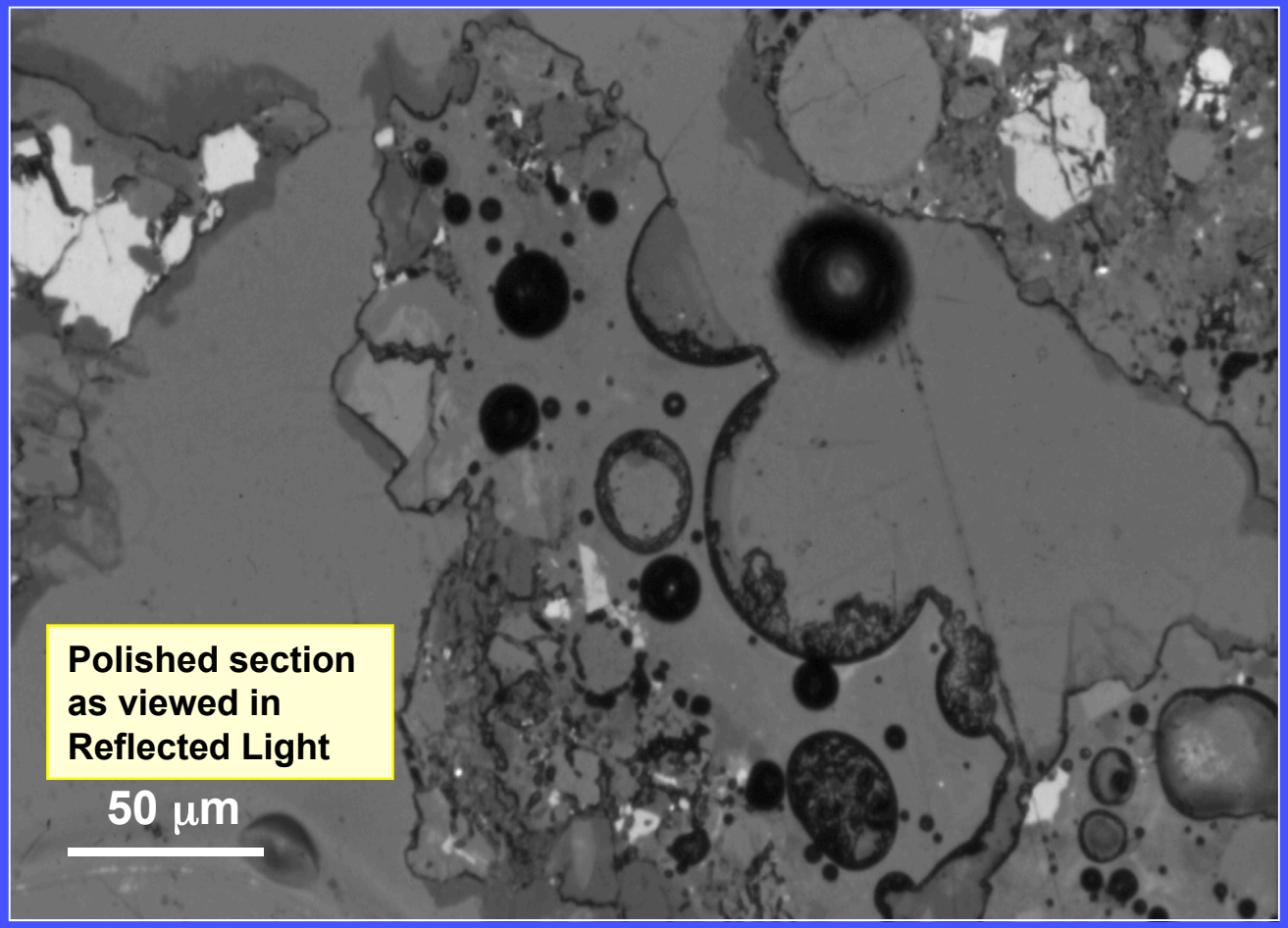


Mare-Soil Agglutinate

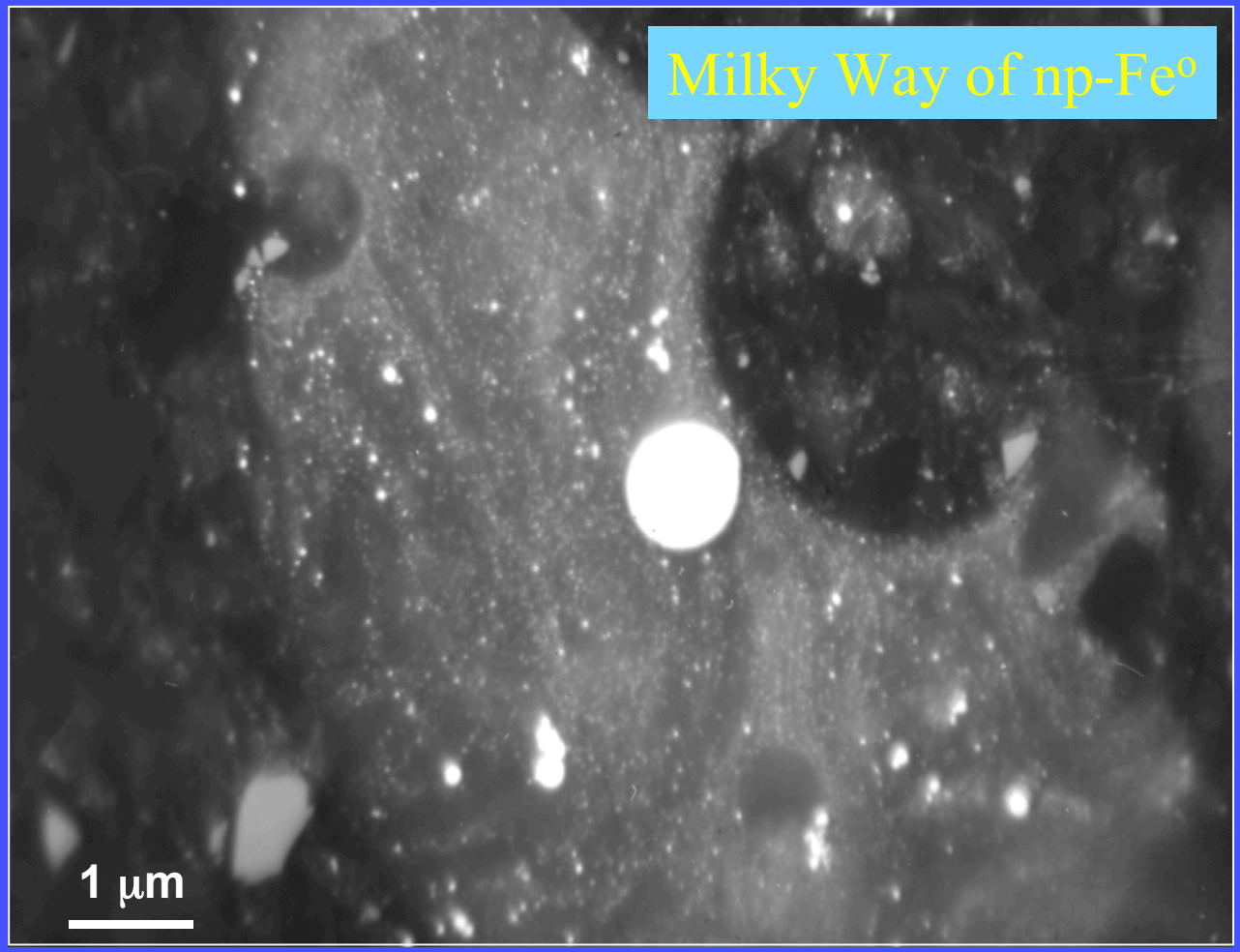


Pieces of minerals, rocklets, and glass cemented together by shock-melt glass

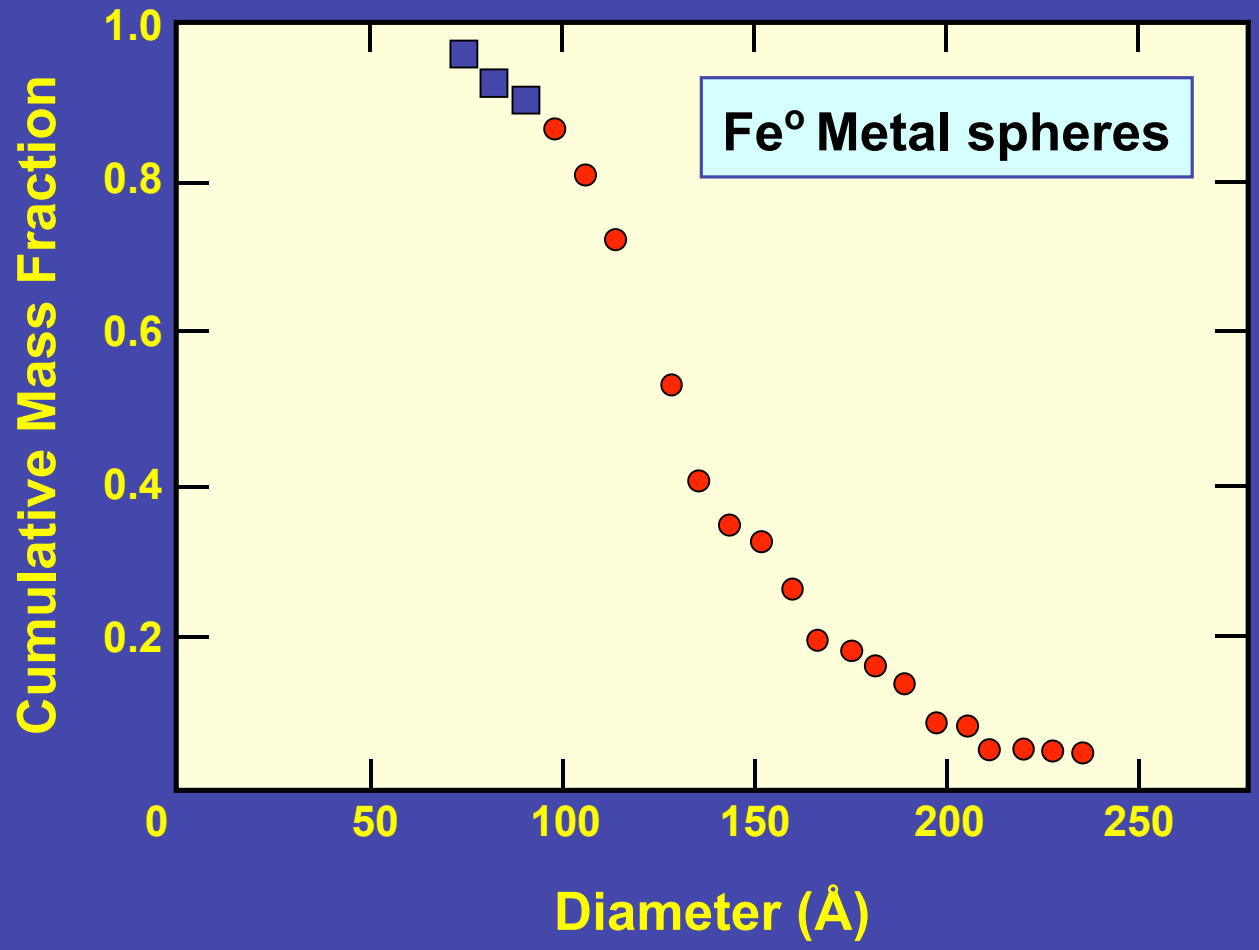
Mare-Soil Agglutinates



SEM BSE-Image of Mare Agglutinitic Glass



Courtesy – Dave McKay



TEM-measured Size Distribution of Fe Metal Spheres in Agglutinitic Glass of Apollo 11 Soil 10084

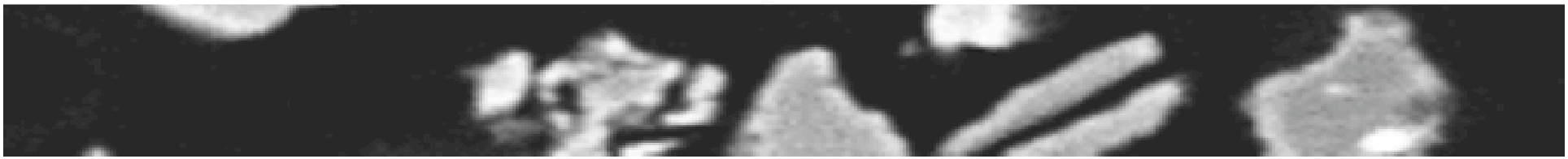
NANOPHASE Fe° in VAPOR-DEPOSITED PATINAS (RIMS)

on VIRTUALLY ALL GRAINS of a MATURE MARE SOIL

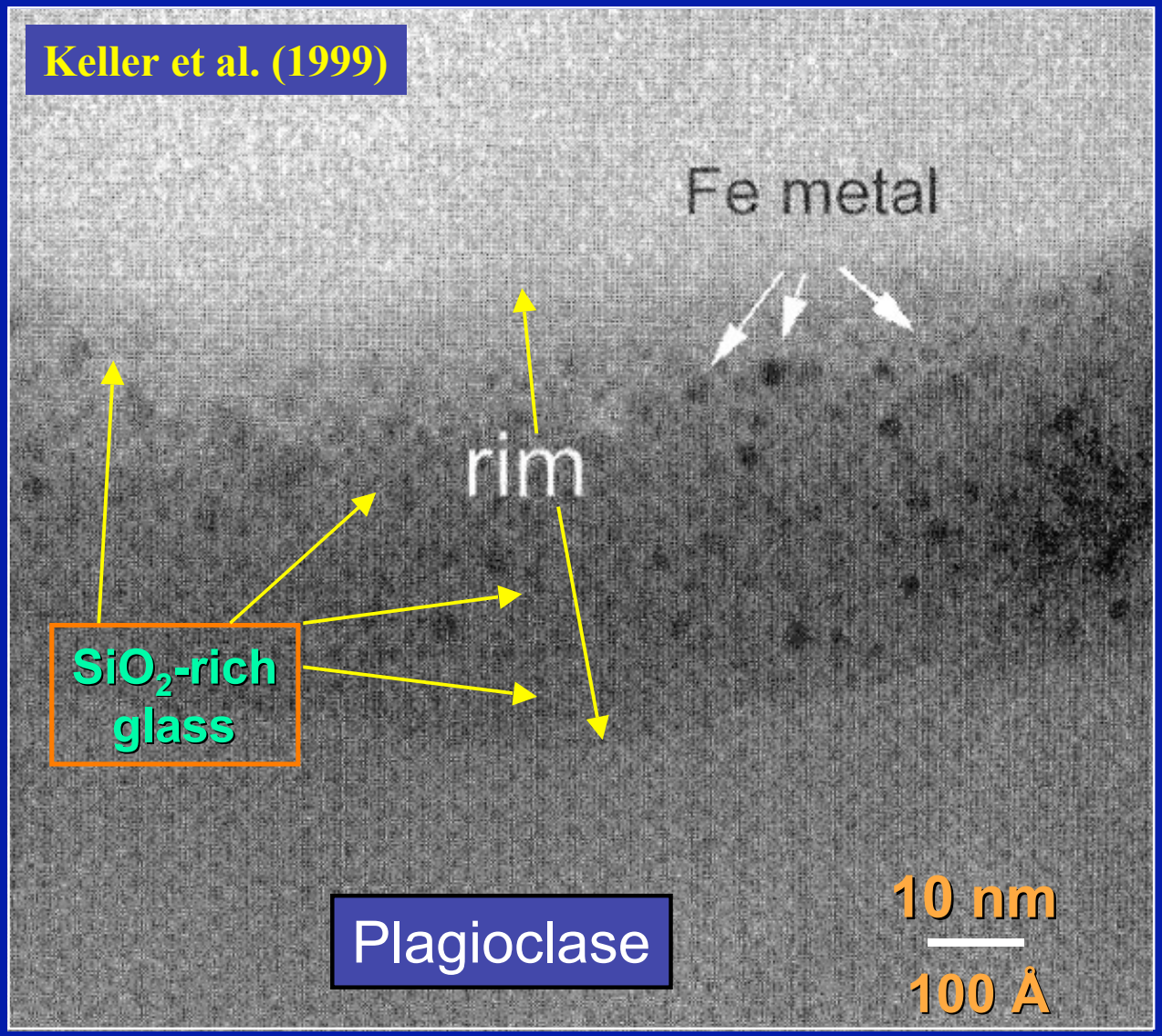
PROVIDES an ADDITIONAL and ABUNDANT SOURCE

for the GREATLY INCREASED I_s / FeO VALUES

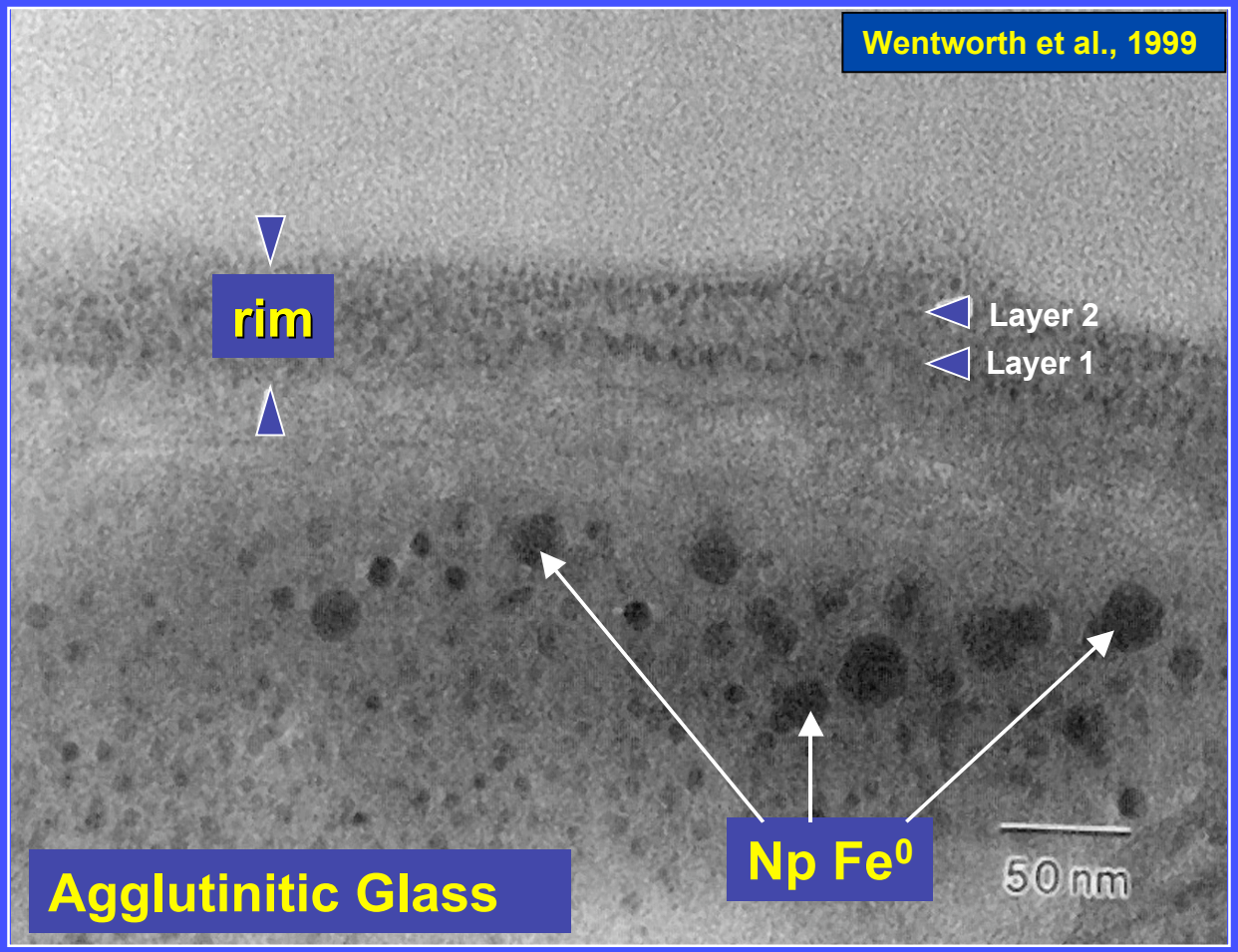
for the FINEST GRAIN SIZES.

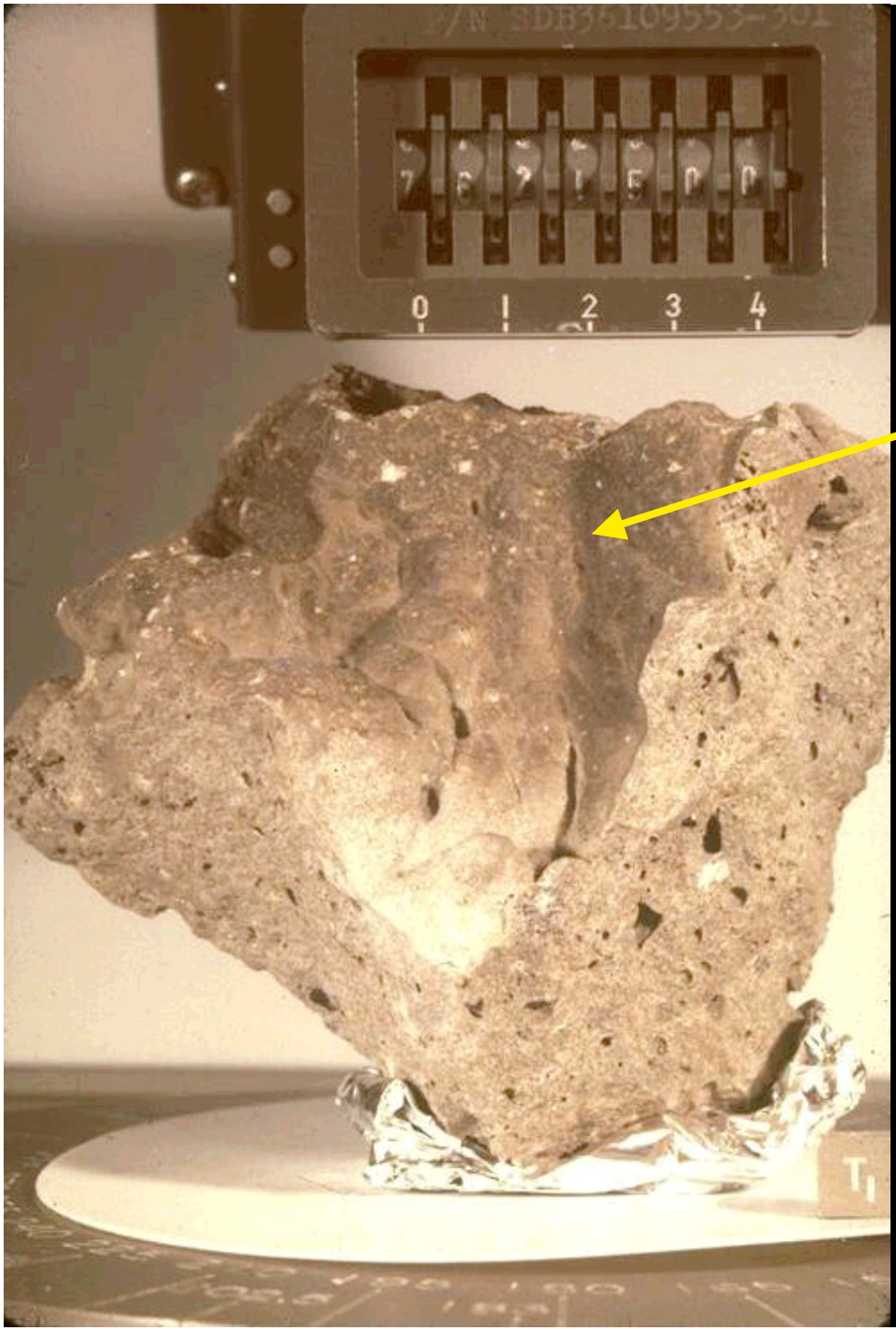


Vapor-Deposited Nanophase Fe^{o} on Plagioclase



Multiple Layers of Vapor Deposition





LARGE VESICLE ORIGINALLY OPEN TO SPACE FOR AT LEAST 800,000 YRS

MAGNETIC PROPERTIES OF LUNAR SOILS

- Magnetic Susceptibility of Soil Particles Increases as Grain Size Decreases;

- Effects of Vapor-Deposited Nanophase Fe^{o} are a Direct Function of Surface Area and Most Pronounced in the Finest Grain Sizes;

- Virtually All <10 μm Particles are Easily Attracted by a Simple Hand-held Magnet, Plg, Pyx, Ol, and Agglutinitic Glass alike.

Lunar Dust Effects: Must be Addressed by Engineering Design before any Commercial Presence on the Moon can be Fully Evaluated.

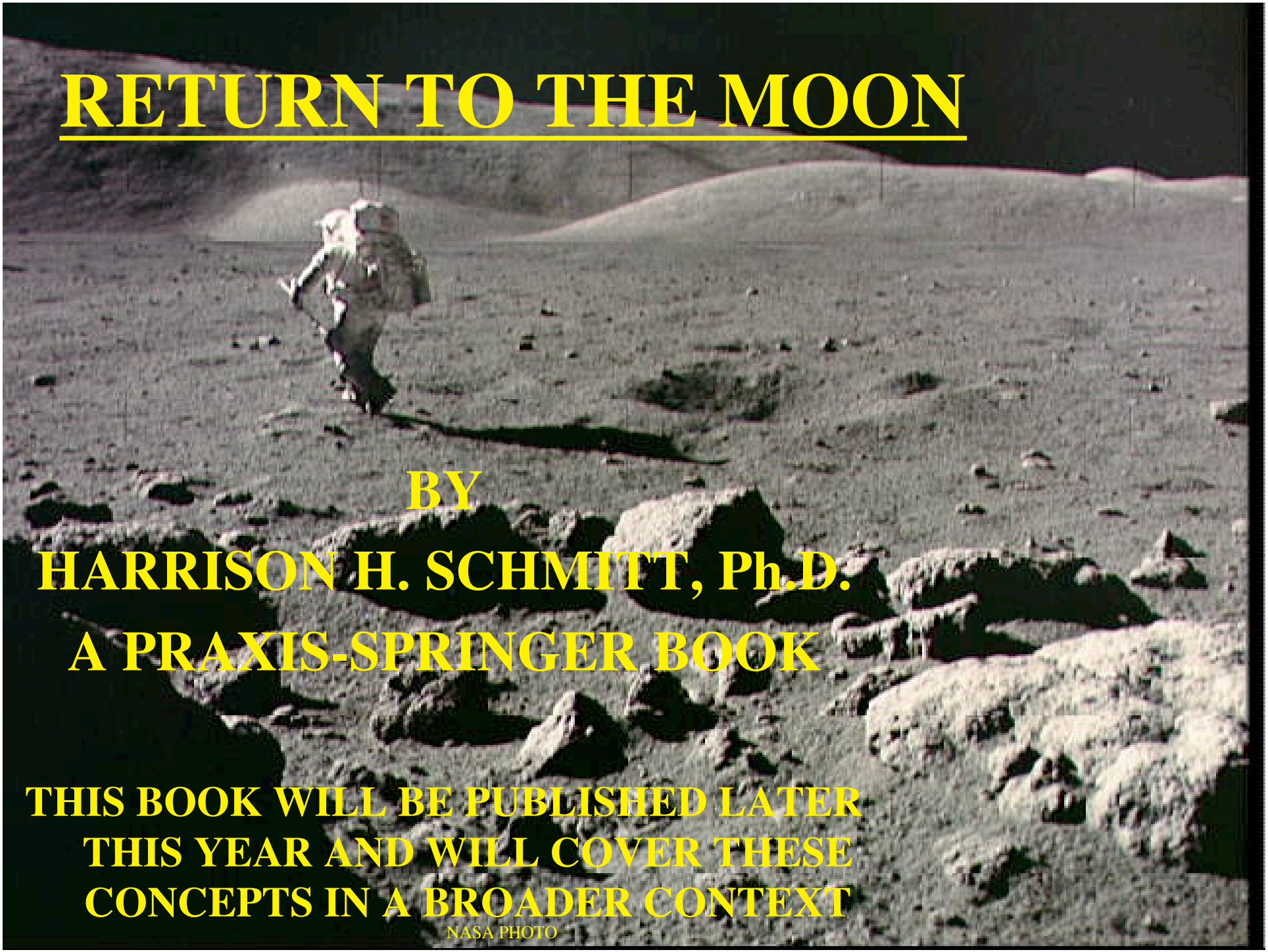
- ✓ Potential for dust **coatings** on seals, gaskets, optical lens, windows, electrical components, et cetera;
- ✓ **Abrasiveness**, with regards to friction-bearing surfaces;
- ✓ Potential for **settling** on all thermal and optical surfaces, such as Solar cells and mirrors; and
- ✓ **Physiological effects** on humans, especially with respect to the lungs and potentially the cardiovascular system in the case of extremely fine particles.

SOLUTIONS: Dust Lock, Magnetic brushes ?? Electostatic Repulsion ?? Seal off by Design

HUMAN EXPOSURE TO LUNAR DUST

- APOLLO 11: TWO INHALATIONS
- APOLLO 12 &14: THREE INHALATIONS
- APOLLO 15, 16 & 17: FOUR INHALATIONS
- PHYSIOLOGICAL EFFECTS:
  - "SPENT GUNPOWDER" SMELL
  - SHORT-TERM NASAL IRRITATION
  - NO KNOWN LONG-TERM EFFECTS
    - NO SPECIFIC INVESTIGATIONS

RETURN TO THE MOON



BY

HARRISON H. SCHMITT, Ph.D.

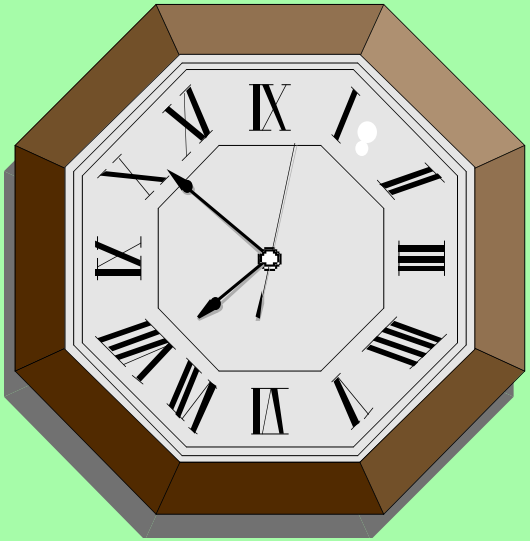
A PRAXIS-SPRINGER BOOK

THIS BOOK WILL BE PUBLISHED LATER THIS YEAR AND WILL COVER THESE CONCEPTS IN A BROADER CONTEXT

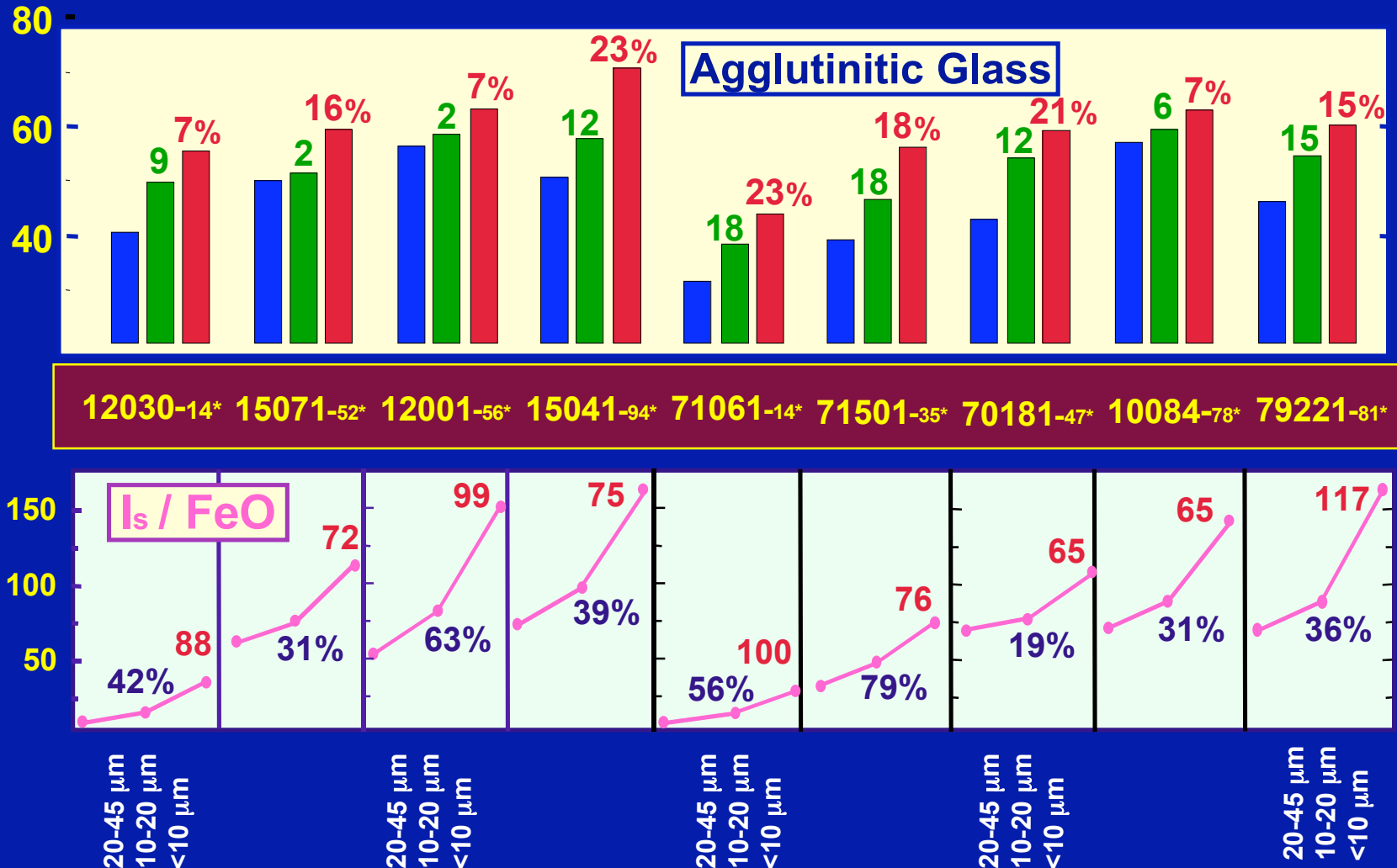
NASA PHOTO

REGOLITH MATURATION

- **BEGINS WITH SURFACE STABLIZATION**
  - **MODIFICATION BY:**
    - **PRIMARY IMPACTS**
    - **SECONDARY IMPACTS**
    - **HYDROGEN REDUCTION OF FEO**
    - **PLASMA GLASS DEPOSITION**
    - **SPACE RADIATION**
    - **INTERNAL VOLATILE MIGRATION**
- **SPACE RADIATION**
  - **COSMIC RAYS**
  - **SOLAR-WIND IONS**



Is/FeO Values Versus Agglutinitic Glass Contents



Small increases in Agglutinitic Glass, BUT Large increases in Is/FeO

Taylor et al. (2001)

FORMATION OF NANOPHASE Fe^0 in AGGLUTINITIC GLASS:

30 YEAR PARADIGM

Auto-Reduction Reaction in Impact-Soil Melt

$$\text{“}FeO_{melt}\text{”} + H_2 = Fe^0 + H_2O\uparrow$$

Solar-Wind Implanted H^+ in Lunar Soil
Causes Reduction of Fe^{2+} to Fe^o
in Micrometeorite-Produced Impact Melt